IRRESISTIBLE MATERIALS

MTR Resist for Reduced LER in EUV Lithography

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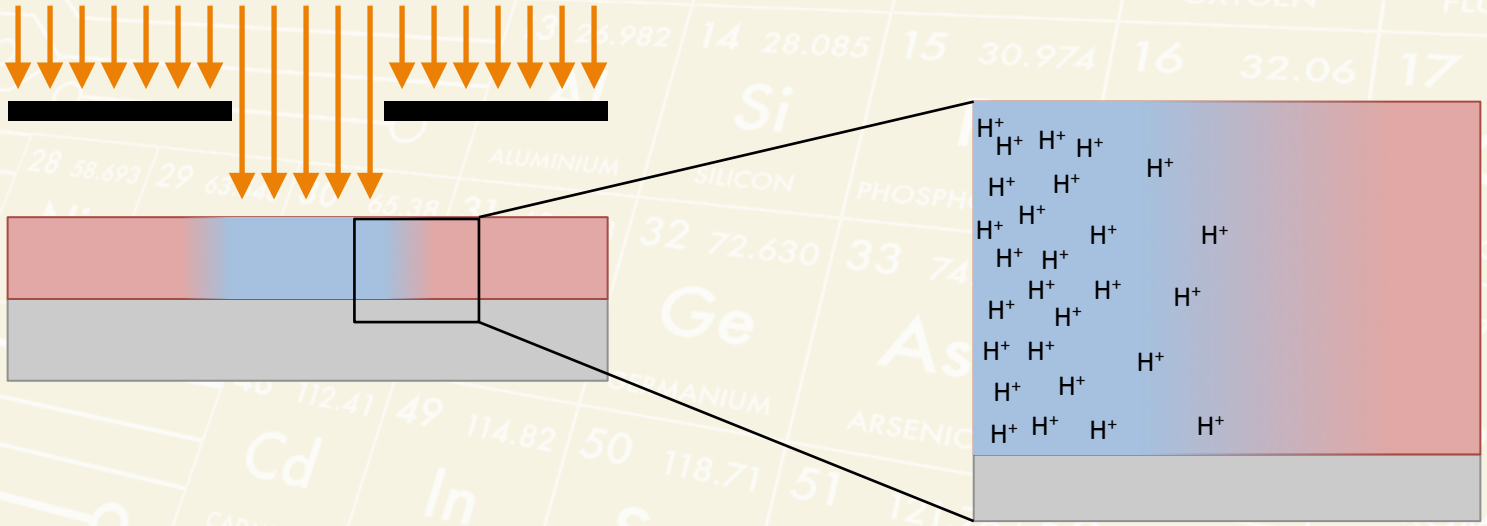
IM

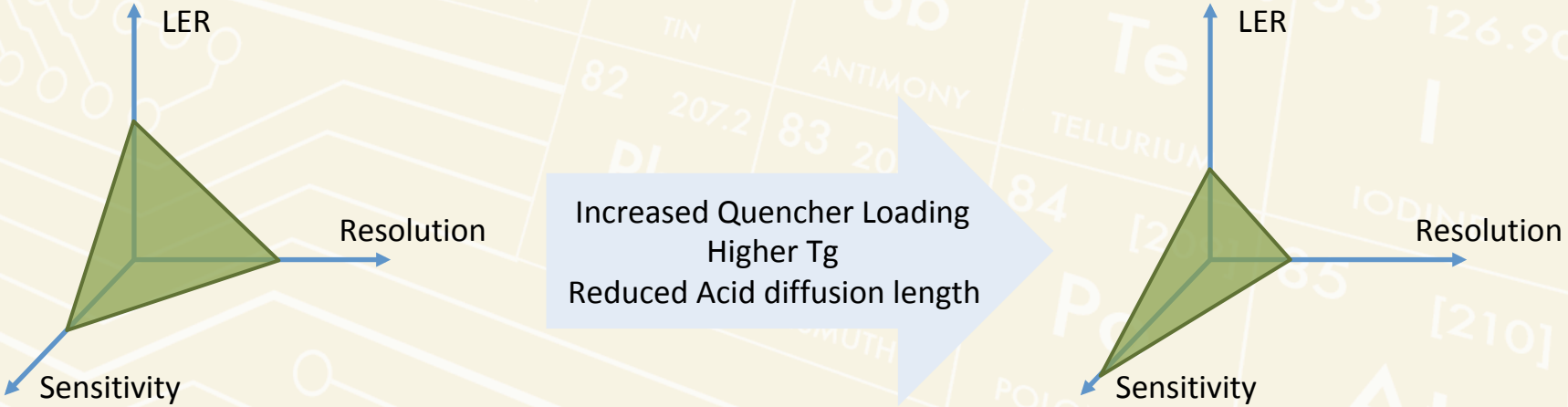
nano-c® nanostructured carbon

Background to Irresistible Materials

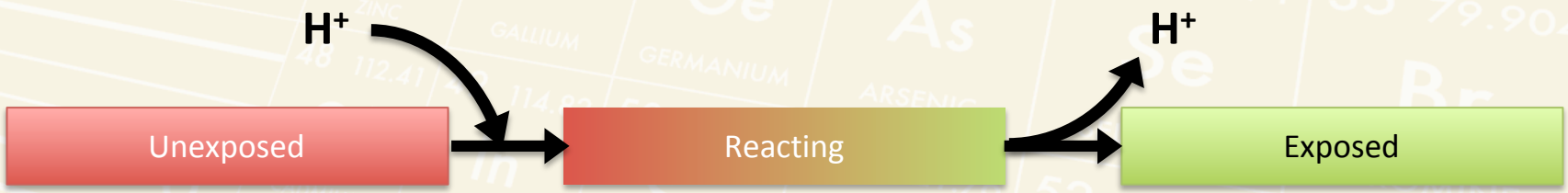
- Irresistible Materials is a UK spin-out company formed to commercialise university research in materials for semiconductor fabrication such as resist and spin-on-carbon
- Developing a new molecular resist system that demonstrates high-resolution capability based on the multi-trigger concept

RLS Control


H+

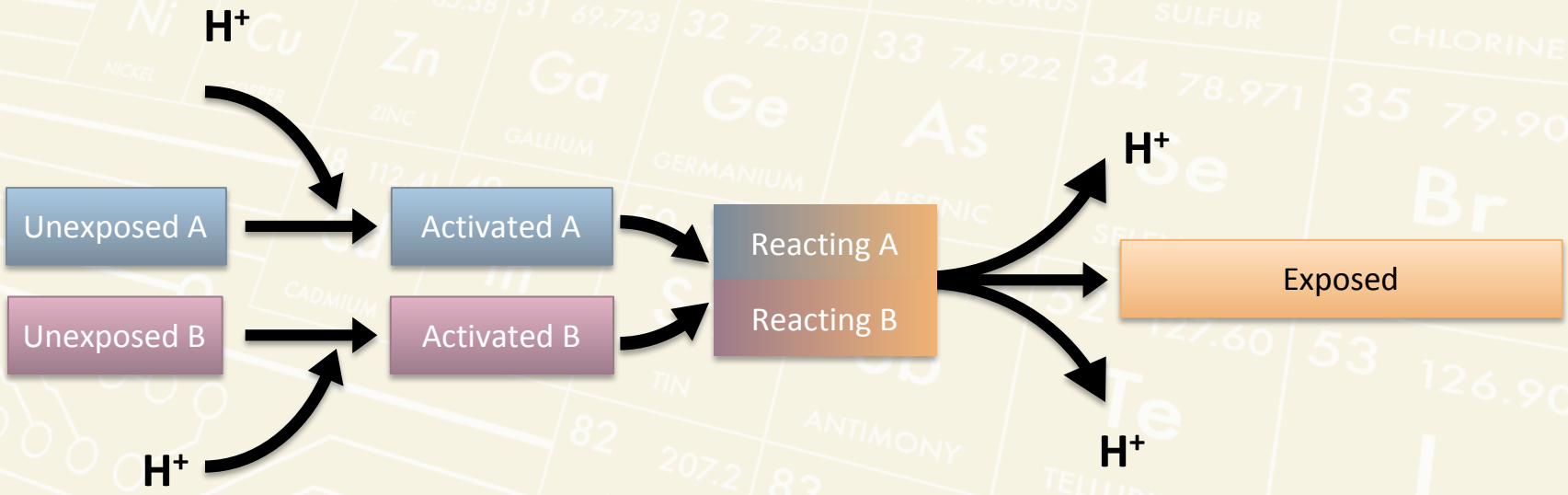

LER
Resolution
Sensitivity
Increased Quencher Loading
Higher Tg
Reduced Acid diffusion length
LER
Resolution
Sensitivity

Traditional Chemically Amplified Resist (CAR)

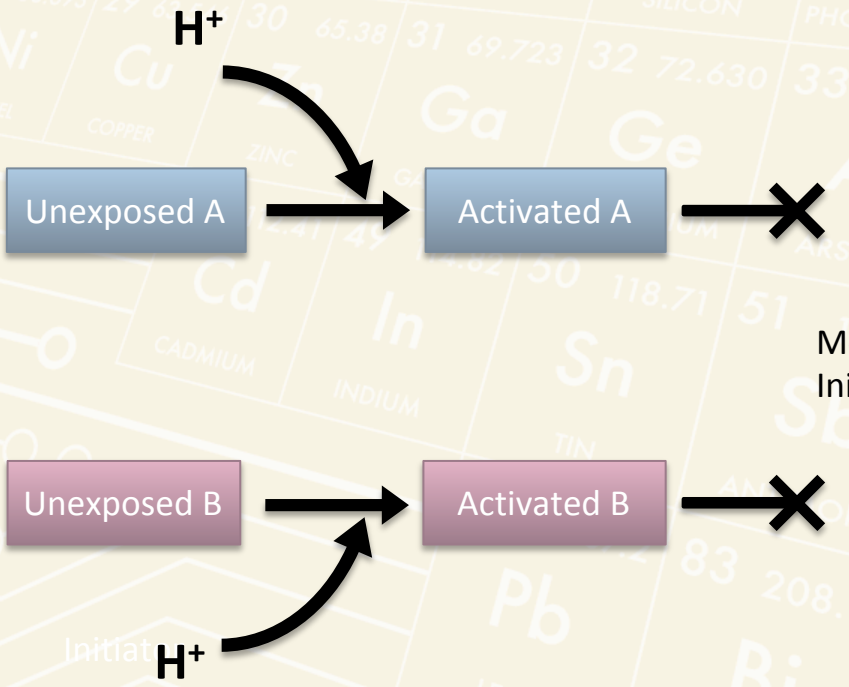


Traditional Chemical Amplification

Multi Trigger Resist (High dose areas – center of features)

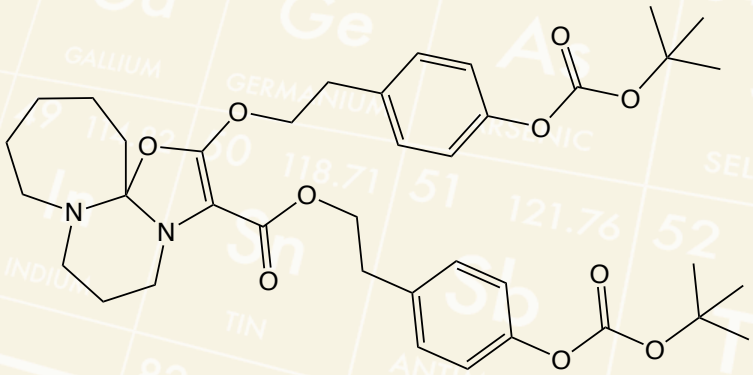


Multi Trigger Resist (Low dose areas – feature edges)



IM Multi-Trigger EUV Resist

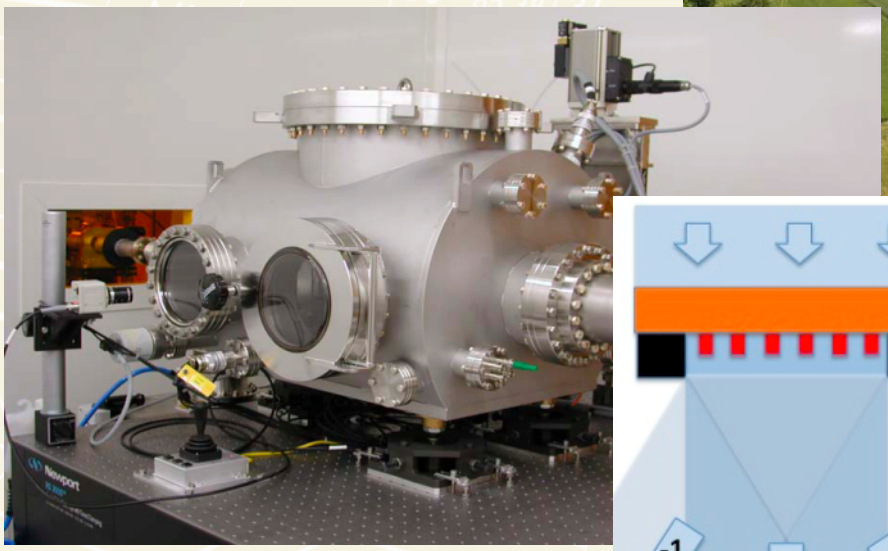
The Irresistible Materials Multi-Trigger resist is a negative tone molecular resist, based on a proprietary resin (xMT).

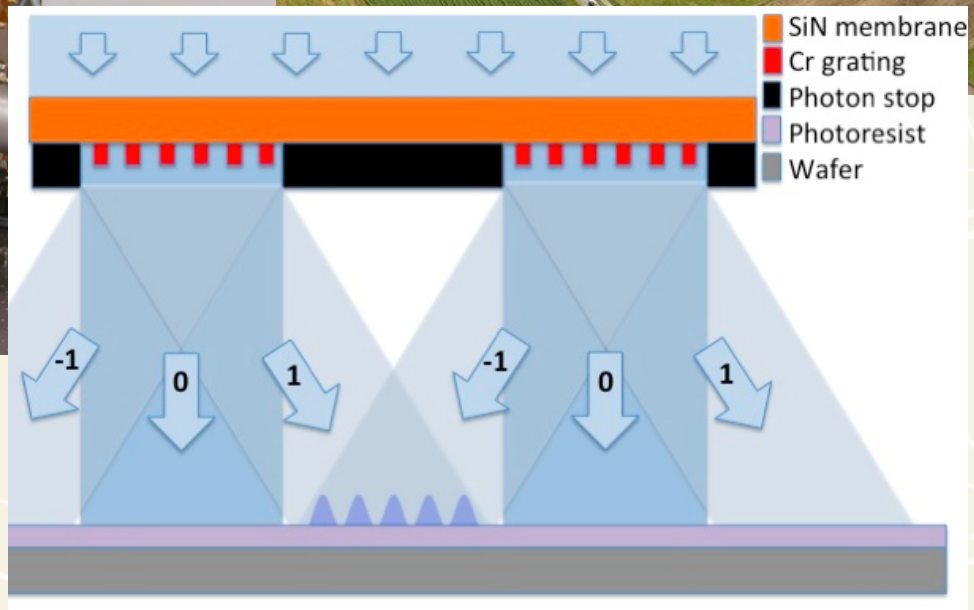


Coating is from standard industry casting solvents, and development is in accepted negative tone developers including n-butyl acetate. Standard etch processes are applicable.

EUV exposure - PSI

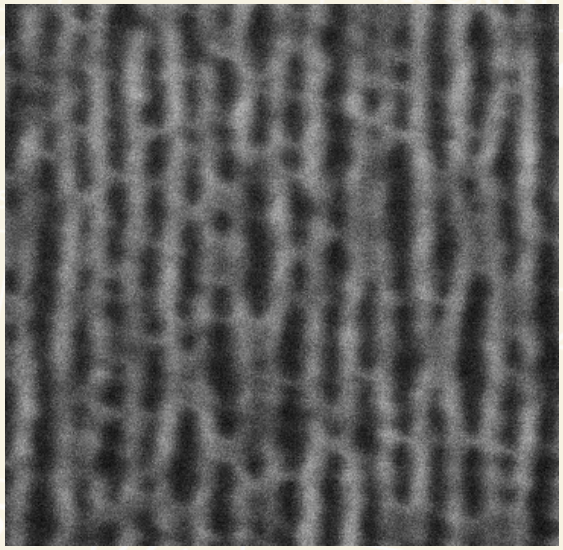
Swiss Light Source





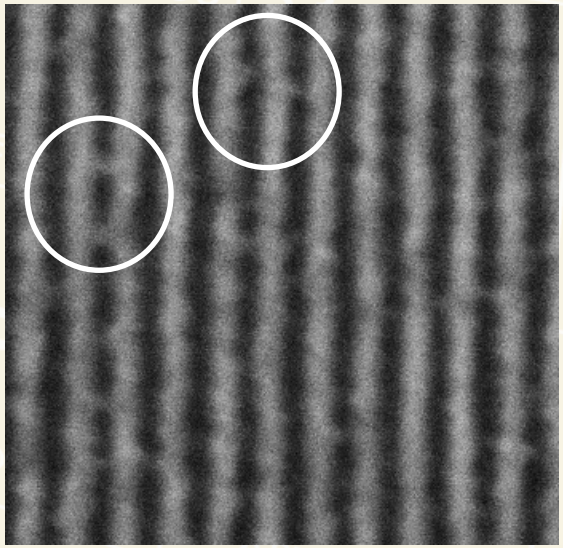
Interference Lithography

Improving Line Edge Roughness



Causes

- Pattern collapse
- Microbridging
- Resist mechanical strength
- Resist Stochastics

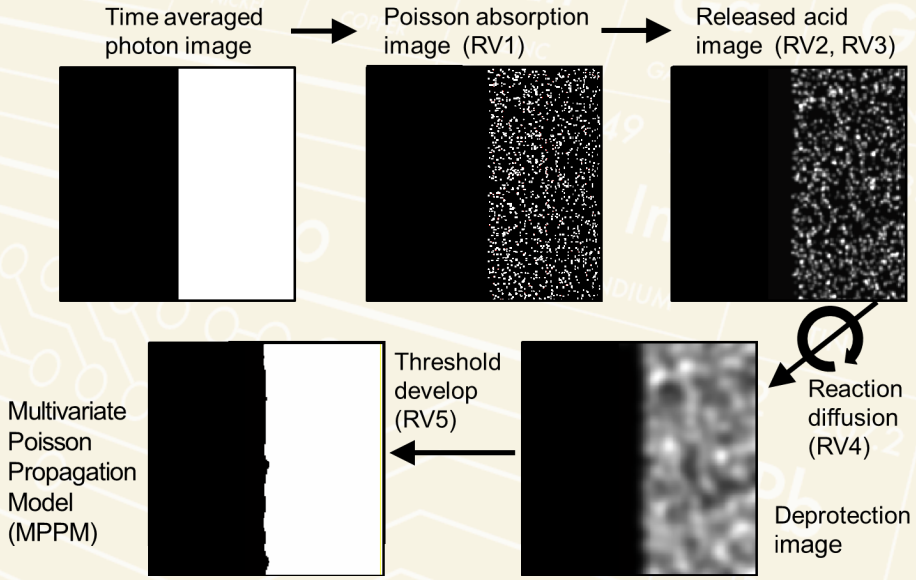


Approaches

- Increase multi-trigger component
- Increase crosslinking groups
- Addition of high Z sensitizer
- Optimize the film thickness
- Optimize the MTR ratio

Quencher Stochastics

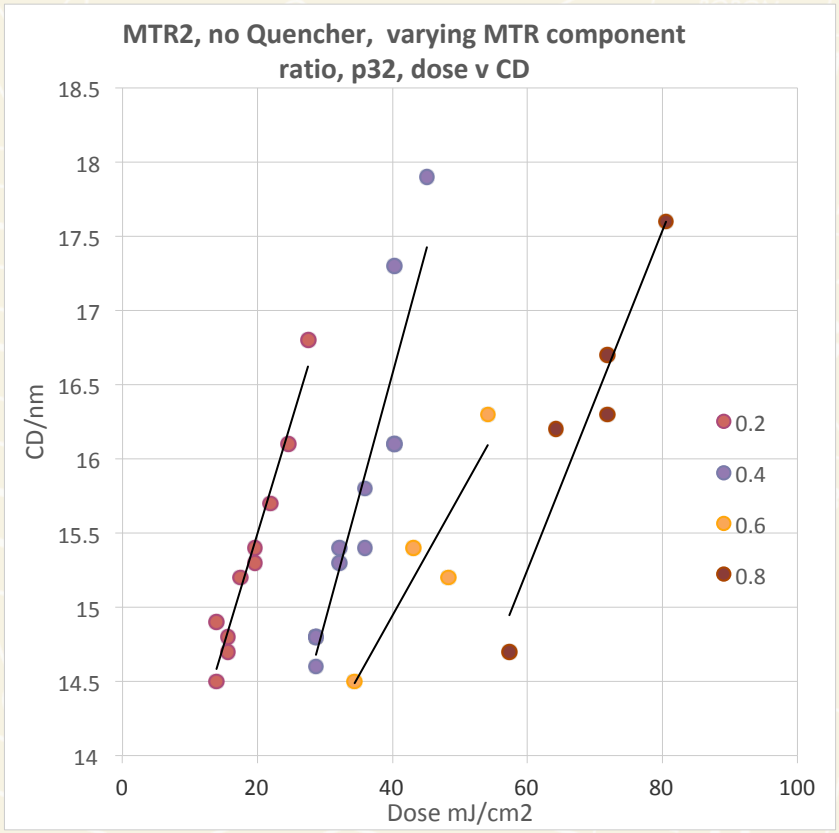
The incorporation of quencher is typically at low concentration and contributes significantly to material stochastic variability.

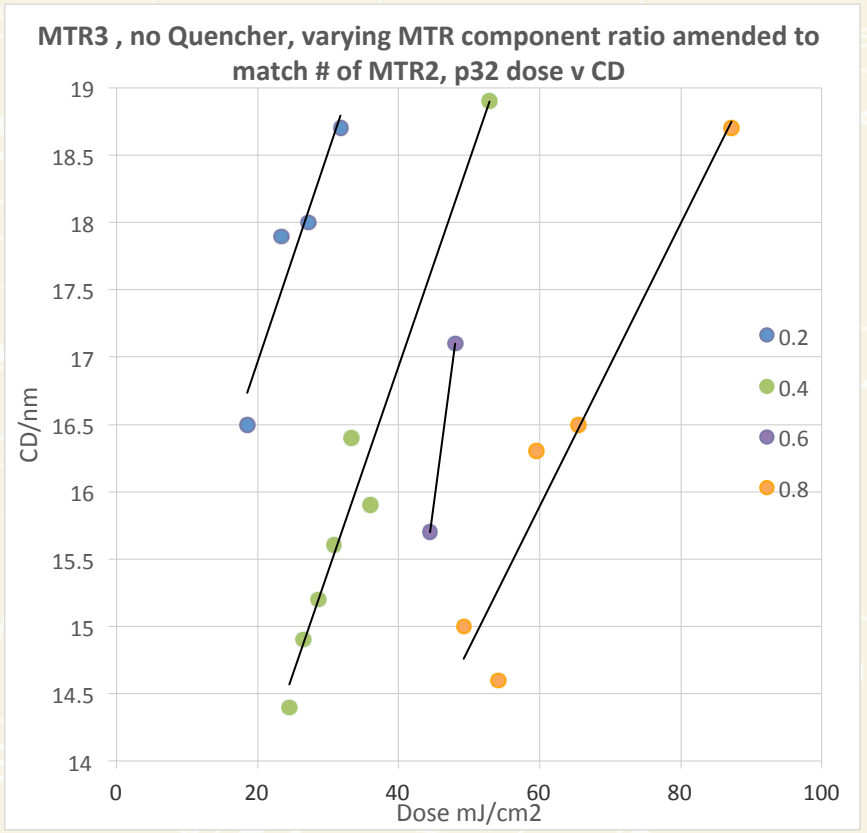


Stochastic Term(s)	Modeled LWR (nm)	
Photon	1.9 ± 2%	
Acid	0.9 ± 2%	
PAG	0.6 ± 2%	
Quencher	1.8 ± 2%	2.2 nm
Protecting Groups	0.2 ± 2%	
ALL	2.9 ± 2%	

From: Patrick Naulleau, "EUV lithography patterning challenges" in Materials and Processes for Next Generation Lithography, Elsevier 2016.

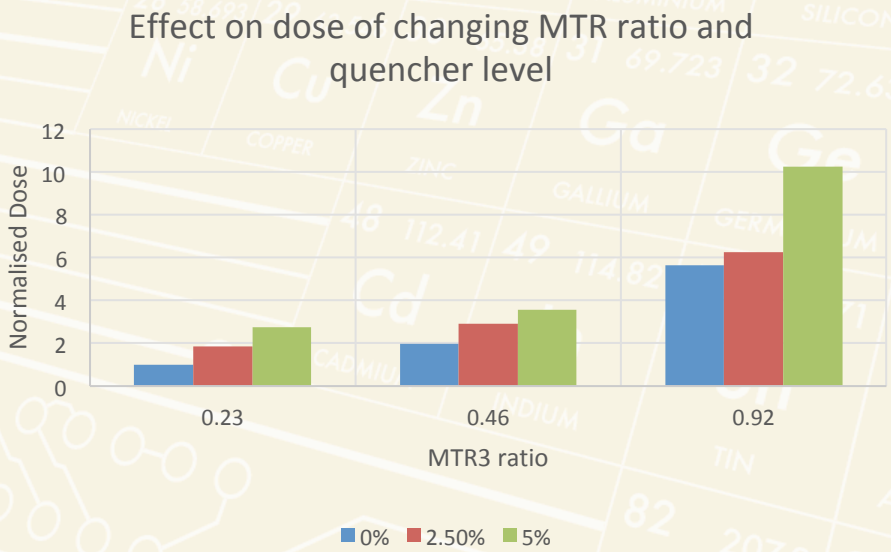
Multi-Trigger Component Ratio

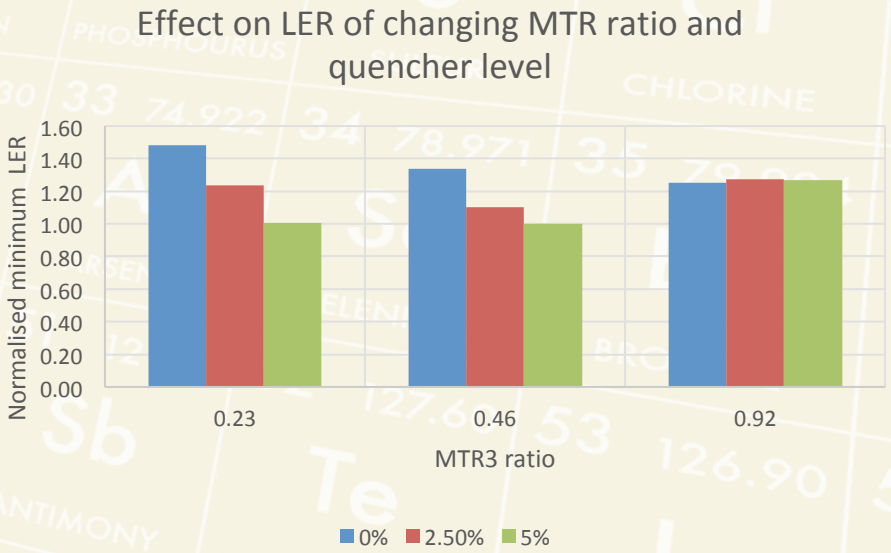




MTR2 ratio	LER/nm	Dose(mJ/cm²)	MTR3 ratio	LER/nm	Dose(mJ/cm²)
0.2	6.5	23.3	0.2	5.9	13.8
0.4	4.8	36.6	0.4	4.8	33.9
0.6	5.1	53.0	0.6	4.6	45.2
0.8	6.1	66.5	0.8	4.7	61.0

Effect of quencher on LER



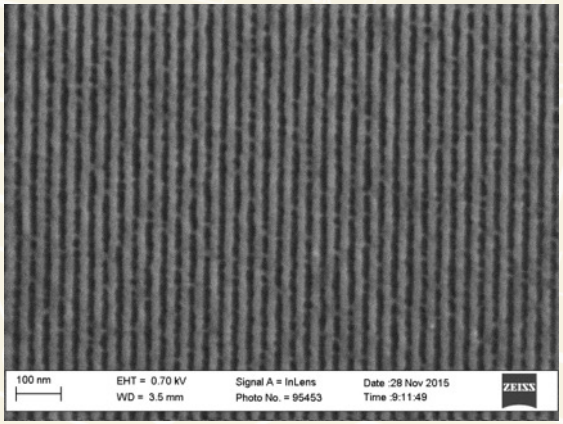


- 14nm and 18nm lines patterned at relaxed pitch to minimise bridging
- Increasing MTR ratio increases dose – large range achievable
- Adding quencher has larger effect on LER for low MTR ratio, and negligible effect on LER at high MTR ratio
- Best LER occurs with 5% quencher loading at 0.46 ratio, 0.23 ratio similar

Low MTR action – increasing quencher improves LWR (PSI)

MTR1220

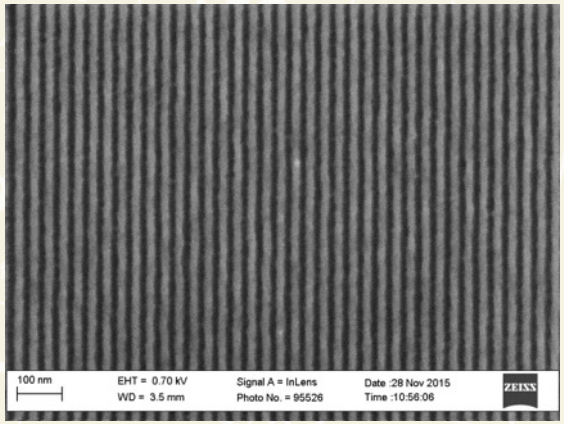
No quencher



30.4mJ/cm^2
CD 16.4nm
LWR 6.08nm

MTR1230

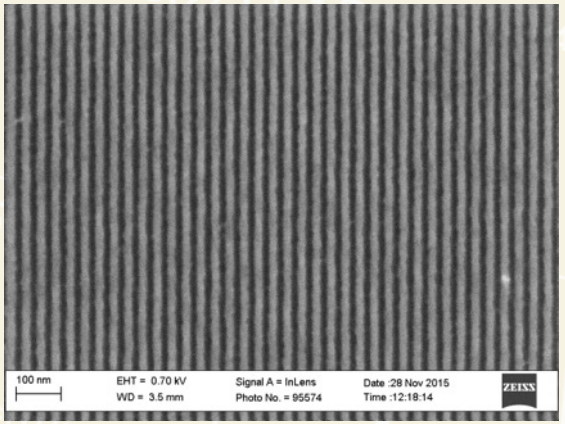
Low level quencher



45.3mJ/cm^2
CD 15.8nm
LWR 4.07nm

MTR1200

High level quencher



59.7mJ/cm^2
CD 16.2nm
LWR 3.36nm

Increasing dose
Decreasing LWR

Higher MTR action – towards Multi-Trigger at PSI

No quencher

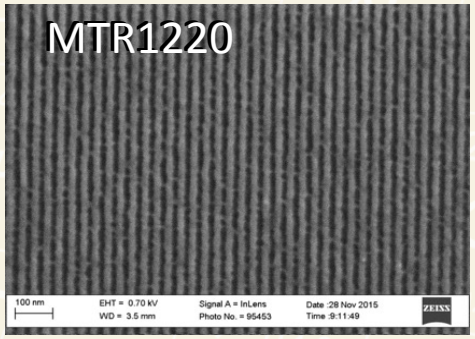
Low level quencher

High level quencher

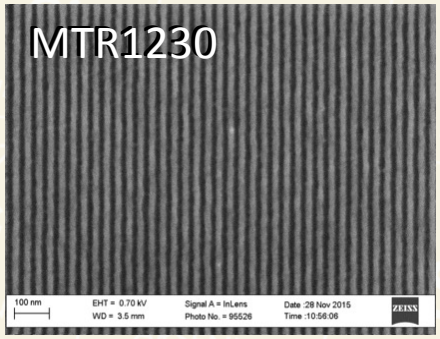
Low MTR action

Increasing MTR
Increasing dose
Decreasing LWR

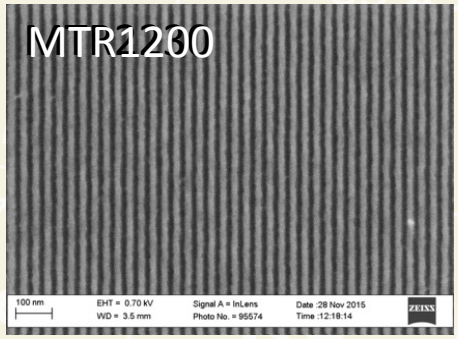
Higher MTR action



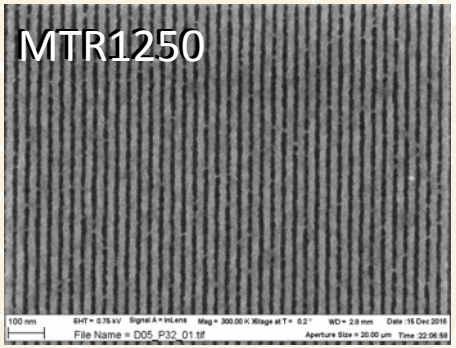
Dose to Size 30.4mJ/cm^2
LWR 6.1nm



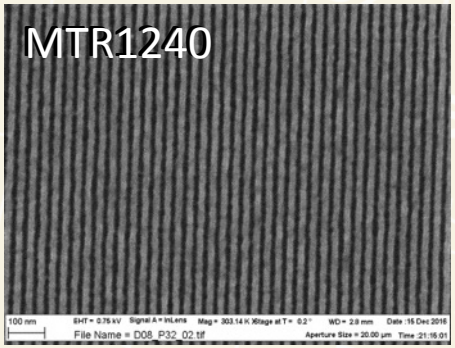
45.3mJ/cm^2
LWR 4.07nm



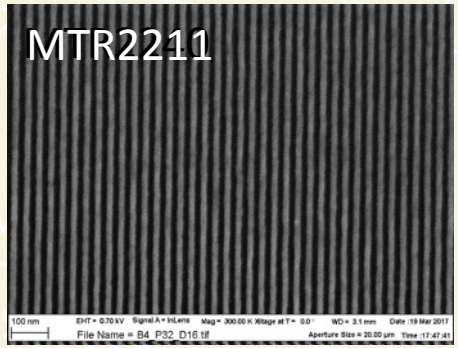
59.7mJ/cm^2
LWR 3.36nm



Dose to size 38mJ/cm^2
LWR 4.8nm



45mJ/cm^2
LWR 4.1nm



47mJ/cm^2
LWR 2.5nm

Increasing MTR
Increasing dose
Decreasing LWR

Conclusions

- Material stochastics has an important effect on the LER of the structures printed.
- Optimizing the MTR ratio significantly reduces the LER.
- Quenching effect on LER saturates for high MTR ratio.

Acknowledgements

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